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DETERMINATION OF THE EARTH FORM

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ABSTRACT

The article will illustrate the principles informing about the different methods capable of giving the Eart´s form and dymension.

A hystorical review will follow, of the main steps in the evolution of these methods also indicating their future expected developments. First, I will expose the different methods capable of giving the form and dymensions of the body "Earth" in space, I will analyze successively the main hystorical steps of this determination up to the modern era, which due to the extension of: triangulations, international exchange of informations, evolution of measurement instruments and caluculus, and above all, to the emergence of the satelites has in a few years allowed to obtain important progress in the knowledge of the Eart´s form.

MATERIALS AND METHODES

The principles of determining the form of the Earth.

On a first approximation, the Earth can be considered a non-defectable solid body whose external surface in any point is connected to a fix direction vertical to the place, which has a very important function in observations and in calculations. In order to simplify, we will suppose that the Earth is fixed in the space field, thus that any star constitutes a known direction whose characteristics are taken out of the ephemerides given by the fixed observers for the position astronomy.

The verticals are not only fixed directioons connected to any point of the topographic surface, and correspund to the force lines of the terrestrial field which has two main properties, i.e:

- the range field in a potential;
- the potential is the newtonian attraction potential.

The knowledge of these properties makes possible finding some of means to obtain the external form of the body in space, The Eart. These properties are classified in four categories.

- rurely geometrical methods;
- classical geodezy and astro-geodetic survery;
- gravimetry;
- dynamic geodetics through satellites.

Fundamental Unknown of geodetics.

In this case we are dealing with purely geometrical elements, which correspond to the external shape of our planet, and other elements that we call dynamic since they cause the intervention of direction and intensity of the gravitational field.

<u>Geometric unknown of position</u>

A point M on the Earth surface or in its close reach can be determined with all the rigour:

- either through its Cartesian coordinates (x, y, z) in a reference trihedral with the center I, whose axes have a movement perfectly known according to time;

- or through its spiral coordinates, defined considering the normal Mm conducted from M to an elipsoid of revolution with the center in T;

λ = longitude of Mm in the Txyz triedr;
φ = latitude;
Mm = H = ellipsoid height;

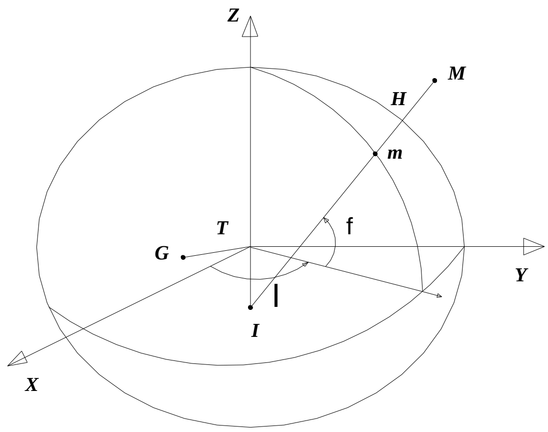

Fig. 1

The purpose of a national or regional geodetic is to determine the set of points M that intersect it, in a unique system associated to a revolution ellipsoid E.

<u>Gravitational field</u>

In the tetriedr from fig. 1 the following vector can be defined $g = MP$, gravitational acceleration gravitației in point M, called "gravitation".

The <u>direction of g is given by the astronomy of the position</u>

φ¹ = astronomic latitude = the angle of MP with the equatorial plan TXY;

λ¹ = astronomic longitude = the angle of the direction of the defined plan of (MP,Z), called the meridian plan, astronomic with the reference plan txz.

The intensity of g is given by the gavimetric measurements and with the help of the presupposed values known in any point of the terrestrial surface, it is possible to calculate the exact form of this compared to the gravitation center G of our planet.

<u>The correspondence among the geometric elements and those of the gravitation field</u>

In geodetics, all delicate problems derive from the fact that the elements are measured on the surface of the globe: distances, directions, differences of altitude and latitude and because it is reduced through calculation to the mathematical theoretic model, *an ellipsoid* of dimensions and position, within arbitrary limits.

If the ellipsoid of calculation is rightly chosen, the normal Mm^1 to the geoid is close to the normal Mm to the ellipsoid, h is close to H, astronomic latitude and longitude (λ^1, φ^1) relative to Mm^1 differ through small quantities of (λ,φ) calculated. This huge closeness between the two systems is characterised by the angle ε between the geodetic verticale and the astronomic one; this angle, called *deviation from the verticale* is rarely greater than 10^{-4} radians ($\cong 20``$).

Based on workd some of the fundamental differential relations we reach a formula that helps us to transform the astronomic azimuth of a horizonztal direction, measured through observations of geodetic astronomy, in an geodetic azimuth variable on the reference surface used in calculations.

<u>The importanc of the topographic surfaces. The Exact definition of the searched unknown.</u>

It can be said as a theory the following property

-The measured done on the topographic surface (and above it), if these are exact enough:

-are ideal to give us the form of this surface and the function W(x,y,z) for it and above it;

-are not ideal to give data about the inner structure of the terrestrial globe (for this, gravimetry gives precious indications over this structure, but always with the help of complementary hypotheses).

This result is naturally obvious for the geometric methods, but is also exact for the astrogeodetics and for gravimetry.

The unknowns, scientificall rigurous that we are looking for are:

- on one side, there are the coordinates of (x,y,z) of all the points of the topographic surface;
- on another side, there is the function W(x,y,z) in the exterior of the acting masses.

In order to see how the form of this topograhic surface is characterised we will procede in the following way:

- choose an elipsoid of reference (a,α);
- any point will be defined :

  (λ,φ, HN) – geodetic longitude;

  - geodetic latitude;
  - normal altitude (the result of the precision survey)
- the theoretical potential is calculated in every point;

  W(λ,φ,HN) or W(x,y,z)
- the confruntation between this theoretic potential and the effectively observed on represents the difference between the reference model and reality.

Quantity:

$$DH = \frac{Wteoretic - Wobservat}{g}$$

is the real magniture (that can be represented cartographically) which shows the form of The Earth regarding the chosen reference surface (the notation DH is identified with the notation Z used in the formula of gravimetry și astro-geodetics).

Clasically the same definitions as above apply in order to esablish the map of the *geoid,* reducing all the measures to the altitude 0 (HN=0) with operations that always have a great part of arbitrary in them.

1. The purely geometric Methods

These methods include determining the coordinates (x,y,z) in a unique system of

a- The classic Method which combines classical geodetics with the zenial distance measurements

The Method is more delicate since the precise observation of the zenial distances is in practice the difficult operation as the observation of the horizontal angles α. In order to correct the refraction, numerous determinations must be made, absolute to the zenial directions, like the lines of the graviational force.

b - The use of altitude objects.

Fotograpy on a stellar background is a classical methos in which the verticals are used as intermediary elements of observation and calculation. The stellar reference intervines as a correction of unsistematic frequent orientation.

2. Spacial Trilateration.

It was used in USA in order to connect among themselves the isles of thePacific.

Astro-geodetics is a methos that starts from the fact that the gravitational field derives from a potential. Taking into considerations the altitudes, the fundamental diferentail relation is:

$$\Delta H_B^A = \Delta h_B^A - \frac{\varepsilon_A + \varepsilon_B}{2}\Delta s$$

This relation allows the passage from measured unevenness Δh to altitudes which refer to the ellipsoid (ε_A şi ε_B being the deviations of the vertical). The potential also intervienes for a more rigorous representation.

3. Gravimetry

The simultaneous knowledge of the potentiality *W* and the value of *g* in all the exterior surfaces of the Earth allows the determination of both its surface shape, as well as its actual dimension. On the other hand, this form is determined by comparison to the masses gravity center, in essence this is the result of gravimetry.

Gravimetry is an “integral” method, that is to say that it only has fully efficacy once the surface *S* is fully covered with measurements of *g*.

4. Utility of the satelite observations.

The theory of the dinamics of satellites allows to obtain all the coeficients for the development of potential *W*; the following characteristics must however be noted:

- in practice, this development can be established efficiently only starting with a certain number of ground satellites whose cartesian coordinates (x,y,z) are priorly unknown. It is thus necessary to proceede through successive approximations;

Supposing the potential *W* is known, the Cartesian coordinates x,y,z of the different terrestrial stations need to be calculated;

Supposing the cartesian coordinates x,y,z, are known the potential *W* should be calculated;

- the factor is a homogenity parameter wich by definition is called terrestrial ecuatorial semi-diameter;
- if observations are being conducted from the terrestrial stations only on the stellar background, it is impossible to obtain the scale of the observation network, or to know the GM, which is the same thing. This indetermination can be eliminated with the

help of the geodetic connection between them or two or more observation terrestrial stations through measured Earth-satellites.

- even without a very precise scale, the sape of the Earth shows when the potential, determined through the Clairaut formule, is known.

In practice, once the expression of W is known, the value W(r,φ,λ) is calculated on an elipsoid with known form and shapes: the rest found connected to a medium value *Wo* of the potential on this surface allows to trace a mape of the "geoid", i.e. the folding of the surface of the equipotential *W=Wo* which refers to a determined elipsoid.

CONCLUSION

Undoubtedly, the study of satellites offers a very efficient means of obtaining the development of the potential, in essence given through the variety of distances and the utilised biases.

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